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The Effect of Differential and Traditional Trainings on Electromyographic Changes of Upper Torso Muscles in Performing and Learning Breaststroke Swimming

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Abstract

Introduction: Based on the principles of the self-organization system, making a change in the training composition can lead to more motor learning compared to doing repetitive training. The aim of this study was to investigate the Effect of differential and traditional trainings on electromyographic changes of upper torso muscles in performing and learning swimming breaststroke. **Materials and Methods**: In this quasi experimental study, 36 female swimmers aged 20 to 25 years old were randomly divided into three groups of control, traditional training, and differential training. Individuals of two groups were treated in two traditional and differential ways, and the control group continued their daily activities without any training. Before and after 12-sessions of trainings, the amount of activity in lower torso muscles, including pectorals major, latissimus dorsi, biceps, and triceps, were measured using electromyography respectively. Covariance multivariate analysis was used to compare the pattern of muscles activities and to evaluate the effect of training sessions on muscles activities. **Results**: Twelve sessions of differential training resulted in significant increases in the average of muscle activity RMS in four muscles compared to the control group. However, these changes were not statistically significant in the traditional training group compared to the control group for the latissimus dorsi muscle. Also, after 12 sessions of training, a significant increase was found in all muscles activities between the control group and the differential. However, this increase between the control and traditional groups was significant only in Latissimus dorsi and biceps. The significant increase between the traditional and differential groups was found in pectoralis major muscle. **Conclusions**: The findings of the present study indicated that the differential training are more effective than traditional training in learning breaststroke swimming, which can be due to more effective use of muscles during the training.

Keywords: Differential; Electromyographic; Muscles; Physical Activity; Traditional; Training; Swimming

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Introduction

Motor skills learning is one of the constant challenges for researchers and in recent decades, many studies have been performed to examine training methods on motor skills learning (1). It has been well established that repetitive training are less effective in motor skills learning than random and variable training (2). Bertolo *et al.* investigated that the effect of random and blocked trainings had no significant difference on the performance of the foot step pattern in dancing (3). Based on schema theory, it was shown that variable training could increase learnability. Variable exercise is a type of exercise in which different types of a movement class are considered, which helps create a more stable memory in learning tasks by manipulating the exercise parameters and creating diversity in training (4). The greater effectiveness of variable training has been supported in free throw of basketball (5), training exercise therapy to students (6), fast motor learning with a wheelchair (7), and learning to produce isometric forces (8) Although there is conflicting evidence which has not supported the superiority of variable training (3). The important point is that variable exercise is presented according to the hypotheses of schema theory (9) and is limited to manipulating the tasks parameters with similar intrinsic aspects. Investigations have been performed by changing the distance, angle, weight of the ball, etc., and in fact, the only changes in the training have been the training parameters and tasks (5).

There has been a new debate in recent years on motor learning, known as differential learning, which is based on the dynamic system theory as well as the self-organization of the system using human learning constraints (5). According to this theory, it is believed that the greater the oscillation in the execution of the movement, the greater the learning. These oscillations can include those in the task, muscle activity, environment in which the task is performed, and any constraints in the movement can be included among these oscillations (10). Researches have shown that changing and oscillating training components can lead to a higher motor learning using the principles of system self-organization than repetitive training. An interesting finding is that, contrary to the principles of variable and random training, differential training can improve both acquisition and learning (11). Findings in handball (12), volleyball (10), athletics (13) and soccer players (14) emphasized that differential learning will happen through differential training. Despite these findings, there is still no evidence to support nonlinear practice and learning Breaststroke swimming. Moreover, there are still little evidences regarding the effect of these training on electromyography of muscles.

Electromyography (EMG) is a technique for assessing and recording the physiological characteristics of muscles at rest and during contraction. In real-world conditions, it is possible to understand the physiological effects of these differential trainings on the EMG patterns and to compare them with a repetitive pattern. Also, given its feasibility in real-word condition, it is possible to understand the physiological effects of these training on the physiological nerve patterns of nonlinear trainings. In differential training, training is performed with the manipulation of the training environment, educational tools, and limbs, and in each sessions, a random combination of these training are planned with no specific order for performing them. Therefore, the learner cannot predict it from one repetition to the next and correct the mistakes. meanwhile, traditional training are a type of repetitive training performed without manipulating the training outcomes (15).

The present study aimed to evaluate the effect of differential training on EMG pattern of lower torso muscles in performing and learning breaststroke swimming skills.

Materials and Methods

In this quasi-experimental study, the population consisting the novice female swimmers who referred to Alvand pool in Hamedan and were at age of 20 to 25 years old. All participants were in the beginning stages of their swimming training. Based on Morgan's table, 36 swimmers who met the inclusion criteria were selected by convenient non-probability sampling method, and then, they were randomly divided into three groups of differential training (n=12), traditional training (n=12), and control (n=12). The inclusion criteria consisting, the lack of experience in swimming training and water skills. After obtaining the informed consent and completing the Physical Activity Readiness Questionnaire (PRQ) form, the research process was explained to the individuals by detailed and the research procedures were stared.

Before and after 12-session training in one month (Each session includes forty minutes of training) traditional and differential trainings. At first the muscles signals were checked on MATLAB software. Participants were then asked to perform swimming breaststroke on a simulated board in 5 times, and the patterns of their muscles activities were recorded when moving. The recording was carried out twice, once before the start of training sessions and the second after a12-session training. Their muscles activitis patterns were recorded during the movement. After recording, the Maximal isometric voluntary contractions (MVIC) test was conducted to normalize the muscle activity pattern.

For measurement of muscle activity, the electrode location was determined using Seniam guidelines. The electrode was placed in the one third of the distance between the cubital fossa and the acromion for the biceps muscle and at 50 % on the line between the posterior crista of the acromion and the olecranon at 2 finger widths medial to the line for the triceps muscle. After determining the electrodes location, the areas were shaved and then cleaned with alcohol to reduce skin resistance. Skintact Aqua-Wet electrodes were placed in the determined areas with a distance of two centimeters from center to muscle. The electrode wires were attached to the adhesive electrodes, and an electrode was applied to the bony or neutral areas of the body as the earth electrode. Data were recorded at a frequency of 1000 Hz.

Table 1. Demographic characteristics of the subjects

Variable	Group	Number	Mean (SD)
Age (Years)	Control	12	37.19 (38. 2)
	Traditional	12	25.20 (98.1)
	Differential	12	39.19 (50. 2)
Height (Cm)	Control	12	37.159 (97. 2)
	Traditional	12	25.159 (77.3)
	Differential	12	00.159 (20.4)
Weight (Kg)	Control	12	00.55 (62.3)
	Traditional	12	25.56 (06.5)
	Differential	12	87.54 (75.3)

$$\mathrm{RMS} = \sqrt{\frac{1}{T}\int_{0}^{T} X^{2}(t)dt}$$

For data analyzing, at first the data were entered into MATLAB software. Then, a band-pass butterworth filter was utilized with a cut-off frequency of 10-500 Hz at an order of 4 (16). After normalizing to its maximum value of Root Mean Square (RMS), the EMG signal was calculated based on the following equation. Finally, the mean of RMS was extracted in different muscles, including pectoralis major, latissimus dorsi, Biceps, and Triceps (16).

Mean and standard deviation were used to describe the data. The normal distribution of data was evaluated using Shapiro-Wilk test. Box, Levene, and Bartlett sphericity tests were used to examine the homogeneity of the covariance matrix, assumption of identical variances, and significant correlation between the dependent variables. Finally, covariance multivariate analysis was used to compare the pattern of muscle activity and to evaluate the effect of training courses. Bonferroni post hoc test was used to. SPSS software, version 23, was utilized to analyze the data at a significance level of $P<0.05$.

Results

The demographic characteristics of the subjects are given in Table 1

The covariance was equal in the three groups based on Box test (F=49.5 and $P>0.05$). The homogeneity of variance of scores was established in the test components based on Levene test (F=49.11 and $P>0.05$). Assessment of regression slope indicated that F was not significant at the level of 0.05; therefore, the regression slope of the scores was also established (F=08.5 and $P>0.05$). There was also a significant correlation between the dependent variables according to Bartlett sphericity test (test score F=1.39 and $P<0.001$).

Table 2. Results of covariance multivariate analysis on the mean post-test scores of variables by controlling pre-tests

Test	Value	F	P
Pillai's Trace	932.0	81.20	001.0*
Wilks Lambda	209.0	06.28	0001.*
Hotelling's trace	10.3	45.36	0001.*
Roy's Largest Root	86.2	31.68	.0001*

** Significant different at P<0.05*

Considering that for confirming these assumptions, the covariance multivariate analysis was used.

The results of covariance analysis on the mean post-test scores of variables in latissimus dorsi, biceps femoris, pectoralis major, and tibialis anterior muscles have been reported with control of pre-tests. These results showed that there was a significant difference between the three groups in terms of mean muscle activity and its mean time in at least one of the RMS variables (Tables 2 and 3).

Based on the results of covariance analysis, after removing the pre-test effect, the group effect on the post-test in RMS of the mean activity time for the pectoralis major, latissimus dorsi, biceps, and triceps was significant. For muscle activity of pectoralis major, 63% of RMS changes included mean muscle activity and 42% of its mean time. For latissimus dorsi muscle activity, 54% of RMS changes included mean muscle activity and 61% of its mean time. For biceps, 62% of RMS changes were mean muscle activity and 54% of its mean time. Regarding the triceps, 44% of the RMS changes consisted of mean muscle activity and 52% of its mean time. The two groups were different in terms of RMS mean muscle activity and its mean time. Bonferroni post hoc test was used to investigate this difference.

According to the results of Bonferroni test in the post-test, the mean RMS activity of pectoralis major (Table 4), latissimus dorsi, biceps, and triceps muscles was significantly higher in the differential group than the control group (Table 5). The difference between differential training and traditional training was also significant ($P<0.05$). Moreover, there was a significant change between the control group and traditional group ($P<0.05$). In the post-test, the mean activity time of pectoralis major, latissimus dorsi, biceps, and triceps muscles was significantly higher in the differential exercise group than the control group. The mean activity time of the latissimus dorsi and biceps was significantly increased in the traditional group compared to the control group ($P<0.05$). There was also a significant change on muscle activity time between the traditional and differential groups for pectoralis major, latissimus dorsi, biceps, and triceps ($P<0.05$).

Table 3. Mean (SD) of variables in pre-test/post-test conditions in control, traditional, and differential groups with the results of analysis of covariance

Variable	Control group		Traditional group		Differential group		Results of analysis of covariance	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test		
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F-value	P-Value
RMS Mean activity of pectoralis major (mV)	46.2 (76.35)	89.1 (12.36)	46.1 (82.36)	68.1 (13.37)	76.1 (39.35)	13.1 (53.37	56.4	*012.0
Activity time of pectoralis major (%)	34 (262)	56 (278	58 (252)	38 (292)	46 (266)	47 (392)	43.7	003.0**
RMS of Mean activity of latissimus dorsi (mV)	44.1 (64.93)	24.1 (24.93	4.2 (38.92)	1.2 (18.93)	8.2 (76.92	35.2 (66.94	12.7	001.0**
Activity time of latissimus dorsi (mV)	36 (211)	47 (218	31 (201)	51 (313)	36 (214)	27 (376	56.4	003.0**
RMS Mean activity of biceps (mV)	88.2 (52.47)	48.2 (24.48	8.3 (88.46)	48.2 (54.50)	4.3 (10.47	28.2 (10.51	50.5	001.0**
Activity time of biceps (%)	32 (291)	48 (296	25 (291)	37 (362)	78 (286)	39 (384)	43.7	013.0*
RMS Mean activity of triceps (mV)	28.1 (76.36)	1.2 (32.37)	8.1 (66.35)	18.3 (71.90)	3.2 (22.38)	55.2 (49.39)	45.6	003.0**
Activity time of triceps (%)	36 (262)	39 (273)	34 (256)	64 (319)	82 (259)	52 (336)	45.6	002.0**

** Significant different at P<0.05, ** Significant different at P≤0.01*

Table 4. Results of Bonferroni post hoc test to compare groups in terms of RMS mean and activity time of pectoralis major and latissimus dorsi

Comparison group	Group	RMS of average activity of pectoralis major(mV)		Activity time of pectoralis major (%)		RMS of average activity of latissimus dorsi(mV)		Activity time of latissimus dorsi (%)	
		Mean difference	*P*-value	Mean difference	*P*-value	Mean difference	*P*-value	Mean difference	*P*-value
Differential training	**Traditional**	-35.2	0.13	-43	0.001*	-96.3	0.01*	-52	0.071
	Control	-72.2	0.01*	-55	0.002*	-08.2	0.01*	-162	0.001*
Traditional training	**Control**	-83.1	0.01*	-12	0.042*	12.1	0.45	-52	0.034*

** Significant different at P<0.05, ** Significant different at P≤0.01*

Table 5. Results of Bonferroni post hoc test to compare groups in terms of RMS mean and activity time of biceps and triceps

Comparison group	Group	RMS of average activity of biceps(mV)		Activity time of biceps (%)		RMS of average activity of triceps(mV)		Activity time of triceps (%)	
		Mean difference	*P*-value	Mean difference	*P*-value	Mean difference	*P*-value	Mean difference	*P*-value
Differential training	**Traditional**	-21.3	0.07	-1	0.321	-09.3	0.18	-13	0.081
	Control	-28.4	0.031*	-52	0.005*	-18.5	0.005*	-52	0.003*
Traditional training	**Control**	-49.1	0.04*	-51	0.040*	-11.2	0.03*	-29	0.061

** Significant different at P<0.05, ** Significant different at P≤0.01*

Discussion

According to the results of the present study, 12-sessions of differential training resulted in significant changes in the mean RMS of muscle activity in four muscles, including pectoralis major, latissimus dorsi, biceps, and triceps. However, these changes were not statistically significant in the traditional training group for the latissimus dorsi muscle. Also, after 12 sessions of training, a significant difference was found in the mean muscle activity between the control group and the differential training in all muscles. However, this difference between the control and traditional groups was significant only in Latissimus dorsi and biceps. The significant difference between the traditional and differential groups was found in pectoralis major. According to the results of this research, it can be said that differential training has a greater effect on the muscle RMS mean as well as the activity time mean of the upper body muscles of swimmers than traditional training. This result is probably due to the fact that one of the visible changes in the muscles during learning is the changes that occur in muscle activity and their co-contraction rate and lead to muscle efficiency. It is possible to evaluate the pattern of learning related to a task and changes in muscle contraction through EMG. Electromyographic models are a reflection of the convergence of interstitial neurons and spinal motor neuron complexes related to central commands (17). Accordingly, it can be stated that both traditional and differential trainings have a positive effect on learning, but due to the use of more muscles in differential training rather than traditional training, the effect of differential trainings on learning are more effective than traditional training.

The findings of the present study were in line with Bozgort's *et al.* study (15), who examined the differences between differential and traditional trainings in learning activities related to football. In that study, 12 football players who were 15 years old practiced in traditional and differential trainings for a 4-week sessions. The results showed no significant difference between groups, but those who performed differential training could improve their skills better than traditional group. Another study by Salzburg *et al.* (11) investigated the differences between traditional and differential training on skating with thirty four 24-year-old recreational skaters. After an 8-week training sessions, differential group had a significant effect on their improved learning compared to traditional group which was consistent with the present study. Wagner *et al.* (12) also studied the effect of differential and variable trainings on the quality of handball throwing parameters in Austrian league and Olympic players. After six weeks of training, a significant improvement was reported in the throwing quality of the players who received differential trainings compared to those who received variable training, which was not in agreement with the present study. This inconsistency can be due to the different nature of the task in different sports. Learning to change one's behavior is a relatively stable skill obtained as a result of practice (12). Also, according to Schmidt's (9) study, although learning is not directly observable, their results are visible. During learning, many changes occur in the central nervous system, some of which contribute to relatively stable changes in mobility. Generally, these processes are not directly visible (9). Therefore, their existence must be proven by the changes which they make in implementation. It is safe to assume that these changes are inferred from the basic processes of the conceptual model of human performance.

One of the growing perspectives related to the organization of the generalized motor program is the impulse timing hypothesis. The main idea of this hypothesis is that the motor program activates motor neurons to stimulate certain muscles. This impulse creates a contraction pattern that can be seen in EMG recording or the force generated. It is worth mentioning that amount of force produced has a complex relationship with the amount of neuronal activity and the force duration, and its onset time is determined by the duration of neuronal activity and the time of activity occurrence. The main role of the motor program is to determine when the muscles are activated, how much force to exert and when to stop. Thus, the mobility plan controls force and time. With the simultaneous activity of the agonist and antagonist muscles around a joint, the central nervous system can adapt the mechanical properties of the limb to respond to the needs of the task while maintaining posture or limb movement (18) Accordingly, it can be stated that a successful training program, which leads to better learning, can result in significant changes in the mean RMS and the activity time of swimmers' muscles. In the present study, it was observed that traditional and differential training caused a significant increase in the mean RMS of the muscles compared to the control group, thereby indicating the effect of these trainings on learning to swim.

One of the limitations of the present study was the impossibility of examining the EMG changes of swimmers in the water and during swimming due to the lack of sufficient equipment. Also, only the effect of traditional and differential training on the performance of swimmers was investigated. It is suggested that the effect of these training on learning in other sports fields be investigated.

Conclusion

Based on the findings, differential training had a greater effect on EMG changes in swimmers' muscles than traditional training, which can be due to more effective use of muscles during the training. This indicates that differential training can lead to more exploration of the movement pattern, and this exploration causes to finding a solution according to the individual's characteristics.

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